UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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June 17, 2013

Martha Maggi, LHG
Environmental Assessment Program
Washington State Department of Ecology
P.O. Box 47775
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Re: Review of Washington Department of Ecology (Ecology) Draft Report -- *Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County March 2013 – Review Draft dated March 29, 2013*

Dear Ms. Maggi:

As requested, the U.S. Environmental Protection Agency (EPA) has reviewed Ecology's report titled *Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County, March 2013 – DRAFT.* Our review was supported by scientists with expertise in hydrogeology and groundwater field studies.

Our comments are enclosed. General comments are presented first, followed by specific comments. Many of our comments pertain specifically to this study and would not apply in other settings. Please feel free to contact us if you have any questions or would like to discuss the comments. Thank you for the opportunity to review this interesting report and we look forward to seeing the final report in the future.

Sincerely,

Marie Jennings, Manager
Drinking Water Program

Enclosure

cc: Sheila Fleming, Risk Evaluation Unit

EPA Region 10 Review of Washington Department of Ecology (Ecology) Draft Report - *Nitrogen Mass Balance: Manure, Soil, Crop Removal, and Groundwater at a Grass Field Overlying the Sumas-Blaine Aquifer in Whatcom County March 2013 – Review Draft dated March 29, 2013*

General Comments

This report describes a complex and comprehensive four-year field study to evaluate nitrogen application and cycling for a grass field receiving dairy manure with a specific emphasis on the transport of nitrate into ground water. This research is very relevant and seeks to address whether current application guidelines are protective of ground water quality. We commend the authors for the effort that they undertook in trying to address all of the relevant parameters and in trying to extrapolate their findings to other regions of interest. We have noted some technical errors, inconsistencies, and issues with data presentation, including the use of inconsistent scientific units. Addressing these issues will strengthen the report.

1. The central theme of the report is evaluating the use of annual excess nitrogen mass balance as a nutrient management tool. This is in effect a partial mass balance, created by calculating input N minus that portion of the output N which is not made up of nitrogen leaching out of the soil; the difference is assumed to be nitrogen that can eventually leach. However, the difference can also be due to that plus artifacts caused by mis-estimates of mineralization, volatilization, or denitrification processes that vary year to year and across the site. The report tries to correlate these calculated annual excess nitrogen values to the "winter mean" (i.e., Nov-Dec) ground water nitrate values, and the results are mixed. In one portion of the report (page 56) you describe a fairly good comparison, because you made (and described) the decision to select one well (AKG725, Figure 46) because it was located in a portion of the site with the lowest potential impact from denitrification. We noted a contradiction in other sections of the report (e.g., page 70) where you show the same data but conclude that this approach is not a reliable method of predicting ground water nitrate. Because the annual excess nitrogen value is a single estimate considering all available data throughout the year, the question arises as to why you chose to compare it just to winter mean ground water nitrate values, and not each of the ground water nitrate values since some leaching occurs yearlong, especially after periodic land application events.

   The report concludes that this is not a reliable tool for predicting ground water impact from nitrate, but then states it may still be useful for balancing plant needs with manure application. How would this calculated value be used? Considering all of the monitoring, measurements and assumptions required to produce this calculated estimate, wouldn't it be more efficient and economical to instead just monitor water table nitrate concentrations periodically, especially in this region where the water table is shallow and easily accessible? This study shows that the amount of manure/fertilizer nitrogen that was applied each year was directly proportional to the annual excess nitrogen mass estimate with good correlation ($y = 0.77x - 304$; $r^2 = 0.9729$). Examination of Equation 8 and Table 8 shows that manure/fertilizer loading was the main driver – atmospheric deposition, soil matter mineralization, ammonia volatilization, and denitrification were all assumed to be constant year to year, and even crop production did not vary much year to year in this case. Another question would be that if this annual excess nitrogen is not proportionately impacting ground water nitrate levels, where is it all going?

In summary, we are left with the understanding that while the annual excess nitrogen mass estimate may not be a good predictor of ground water quality, it may be useful for better matching manure/fertilizer nitrogen loadings to crop demand. However, it is unclear how exactly this would be used and whether the end result would justify the expense of the extensive annual monitoring required.

2. We suggest that the report clearly state upfront that the assessment of direct ground water impact is restricted to the upper reaches of the aquifer only, and may not represent the aquifer as a whole. This is a fairly unique hydrogeological setting in that the shallow water table ranges by about seven feet annually and that each year the soil is saturated in the winter up to near the ground surface (Figure 28). This allows for saturation dissolution of soil nitrate which can cause very high nitrate values, and may allow substantial organic carbon to be transported along with the nitrate. The ground water sample inlets and the low-flow sampling techniques are designed to acquire ground water samples as close to the water table as possible. Assuming that Figure 12 is correct, any high concentrations of nitrate in shallow ground water should "dive" downward as bulk ground water flows beneath the region. If unmitigated by dilution or other processes, nitrate levels measured at the top of the water table that are above the MCL could potentially cause nitrate levels in downgradient drinking water wells to exceed the MCL. According to the data collected from the one deep well beneath the site, nitrate is absent, but ammonium levels are higher than those in the shallow wells.

   There is no nitrate (but again minor levels of ammonium) in the upgradient deep private wells. One explanation for this could be dissimilatory nitrate reduction to ammonium, which occurs when nitrate becomes limiting relative to utilizable organic carbon. The amounts of ammonium produced are so minor that this would not have much impact on the nitrate loading, but if this process were occurring then it would be reasonable to assume substantial denitrification occurring in the aquifer matrix above. It would have been interesting if some downgradient private wells had been sampled, or if some other wells had been installed within the mid-levels of the aquifer or downgradient of this site to evaluate whether high nitrate levels observed in the shallow aquifer have migrated deeper into the aquifer.

3. The stated purpose of the study on page xi was to "... conduct a field study to evaluate the effectiveness of Dairy Nutrient Management Plans (Chapter 90.64 RCW) in protecting the quality of the Sumas-Blaine Aquifer." The results of the field study indicate that the post-harvest soil benchmark used in Nutrient Management Plans is ineffective in preventing groundwater contamination. The study's conclusions do not circle back around to this central question and clearly state whether NMPs are or are not effective as currently implemented, even though the data support a clear conclusion. Presenting a clear, conclusive response to the initial question that was posed would strengthen the report.

4. The report concludes that "estimated excess nitrogen" is a more reliable predictor of groundwater impacts than measuring soil nitrate levels. It is not clear to EPA that this

conclusion is supported by the data. However, if the conclusion is supportable, it is an important concept that should be highlighted. Similarly, the concept that the current soil nitrate target recommendation of 55 lb/acre criteria does not take into account groundwater impacts, and the conclusion that it significantly underestimates the risk to groundwater should be highlighted since that rate is mentioned as "guidance" in the report. The installation of groundwater monitoring wells should be more clearly called out in the recommendations section. In a geographic area like Whatcom County where the water table is very close to the ground surface, monitoring wells would be relatively inexpensive and easy to install, and would provide direct information about aquifer conditions, rather than having to rely on surrogate data with significant uncertainties such as soil nitrate tests.

5. The text should more clearly explain how the level of post-harvest soil nitrate recommended in the guidance could be revised so its use would ensure the protection of groundwater.

6. Overall, the Executive Summary (ES) doesn't stand on its own. Recommend adding a project setting section to the ES. The ES currently lists three bulleted items on page x, 5th paragraph, but this discussion should be broadened (i.e, briefly discuss land use and setting of study area and SBA; regional hydrology, briefly explain how manure is handled, etc.). On the other hand, some of this information could be put in an Appendix showing what was and what was not measured.

7. It would be helpful to add a figure depicting a cross section of the aquifer and vadose zone showing the property boundary, groundwater flow direction, the water table, and the location and depths of the shallow and deep wells.

Specific Comments

Note that the following comments for the Executive Summary should be considered and addressed, if appropriate, throughout the main text of report for the corresponding sections and figures.

1. Page xi, Figure ES-1. The figure should have another note on the legend which defines what appear to be generally incorporated or more urban areas shown in a red tone.

2. Pages xi, 3, and 73. The objective(s) of the study are stated several times, but are not stated consistently. Suggest reviewing, and revising where appropriate.

3. Page xii. Recommend separating program objectives from technical objectives and outcomes or how to use the study. Even though this is the Executive Summary, it would be helpful to state how the objectives support the goal of evaluating the effectiveness of nutrient management plans.

4. Page xii, third paragraph from bottom –Mass balance implies that all outputs and inputs are considered and weighed against each other. This is actually a partial mass balance, because a key component (nitrogen output through leaching) is not directly measured. This should be noted.

5. Page xiii, first line. The word "seven" is spelled out here but elsewhere numbers are referred to numerically. Also, it becomes confusing when sometimes the report refers to

seven vs six wells. Suggest this sentence be rewritten to refer to six shallow wells and one deep well.

6. Page xiii, Figure ES-2. Arrows should be added to and from ammonia (soil block) box to indicate the direction of the process. It would help to write out "denitrification" to identify the arrow leading to N_2 gas, and "volatilization" to identify the arrow leading to atmospheric ammonia. Why are there two boxes for ground water nitrate? What is the significance of multiple arrows and an (errant?) arrowhead in the aquifer matrix?
7. Page xiv, Figure ES-3. The colors in this and other figures could be adjusted so that if the document is printed in black and white, the figures can still be interpreted.
8. Page xiv, bottom paragraph. The statement, "These values provide an approximation of the amount of nitrogen that could reach groundwater if the soil was flushed by water recharging the aquifer in the months following the end of the growing season", assumes that none of this nitrogen has already leached out during the growing season prior to this flush. Because the data shows nitrate spikes following manure application events during the growing season, we can assume that some nitrogen does leach out during this time, hence the annual excess nitrogen would be much higher than fall soil nitrate.
9. Page xv, Figure ES-4. The left axis may be better labeled Total Nitrogen. It is unclear that "mean fall soil nitrate" as shown on the figure is "excess" from this graph or discussion.
10. Page xv, first paragraph. Specify that the target amount is for fall soil nitrate, not excess nitrogen.
11. Page xv. The second paragraph from the bottom refers to green bars in Figure ES-4, but there are no green bars in this figure.
12. Page xvi, bottom paragraph. Define winter mean range as Nov-Dec.
13. Page xvii, first paragraph. Can the report really make any definitive statement about comparing fall soil nitrate with annual excess nitrogen as a better predictor of winter ground water nitrate, at least without doing some statistics? In the absence of numerical values for fall soil nitrate, a best guess analysis does not show a much better correlation with excess nitrogen ($r^2 = 0.41$) than with fall soil nitrate ($r^2 = 0.28$). Page xvii, Figure ES-6 – This figure could be misleading. Suggest the report state that the ground water mean is for one well (AKG725). The excess nitrogen values are incorrectly graphed in Figure ES-6. See Figure 46 for actual values and better graphical representation.
14. Page xvii, Figure ES-6. The left axis label should be Total N (lb / acre), not per year since the years are shown by the different bars.
15. Page xvii, Figure ES-6. See comment 7 above and specifically it would be good to have some description or cross hatching so that even if a black and white printer is used the bars could be better defined (one approach would be to use a label – blue bar is left bar, or use of hatches in one of the bars). In addition, this figure and descriptions deal with mass balance, but the axis is "Excess total nitrogen" and MCL for reference. Overall the point being made comes through, but it could use a few more touches on the figure to make it clearer (would changing left axis to "total nitrogen" vs. "Excess total nitrogen" resolve this issue?).

16. Page xvii, bottom section. Factors affecting groundwater nitrate concentrations – This sections seems to address NMPs but not directly. The text should clarify that the topics below are core elements of a NMP.

    - Nitrogen application rate
    - Timing of manure applications
    - Recharge
    - Tillage
    - Temperature and Soil Moisture
    - Denitrification

17. Page xviii, third paragraph. Chloride will leach out of manure well before nitrate does, so why couldn't the nitrate come from the previous year's manure?

18. Page xviii, last paragraph. Define fall recharge range (Sept-Oct?). Recommend that you provide support for the inference (to avoid appearing arbitrary) – that decreasing fall recharge rates may be contributing to decreasing year-long ground water nitrate values. The overriding driver could be annual rainfall rates, which show a much different trend, being very low in 2005 and high in 2006-2007.

19. Page xix, first paragraph. Can you specify when tilling occurred and in what year?

20. Page xix, Tillage Section. This seems like a very important relationship, but there seems to be some disconnect with the figures and its importance may be overlooked. Should this section reference figure ES-5? While similar to ES-7 the reference to "Nitrate-N concentrations in groundwater the winter after tillage were as high as 45 mg/L-N" seems to more closely match figure ES-5 than ES-7 (which is the last figure referenced and is located above the tillage section). Also note that figure ES-5 does have concentrations that go to 45 mg/L.

21. Page xx, Figure ES-8. It is difficult to figure out what the green bars mean. Suggest this text: "Range of soil nitrate concentrations measured during September-October fall sampling period.

22. Page xxi, first paragraph. On page 13 it says that tilling was done in 2004, not 2005. Also, it seems like selective data are used to support the point. Feb 2005 and Jan 2008 soil nitrate data are listed as high. Why not use Feb 2008 data, which is half the value of Jan 2008? Is it because no Jan 2005 data were available and you are using just the first data point for each year?

23. Page xxi, Figure ES-9. These charts are too small to read. Also, the nitrate MCL line is missing in the AKG727 graph.

24. Page xxii, second paragraph. Statement contradicts previous observation that the annual excess nitrogen method is better than the fall soil nitrate method for predicting winter ground water nitrate. Figure ES-10 – Yellow and blue bars represent ground water nitrate by different methods. Need to add the word "method" after descriptors for these bars. Otherwise it looks like the yellow bar represents mean fall soil nitrate.

25. Page xxii, last paragraph. The second sentence is not clear as written ("concentration of groundwater mixing"). Suggest "...uncertainties regarding mixing of ground water and leachate, and ongoing generation of soil nitrate past the end of the growing season."

26. Page xxiii. Implications for other parts of the SBA. This section could more clearly state the implications for other parts of the SBA. We assume that you are trying to say that this study site has the potential for much greater rates of denitrification than would be found in other parts of the SBA, which would suggest that nitrate levels would be expected to be higher and more persistent at other locations. Text should be clarified. Page xxiii, at the top of page: "...using estimates of excess nitrate in the soil at the end of the growing season is an unreliable substitute for direct groundwater monitoring ..." is correct, but it seems to conflict with other statements and figures in the report which imply that the use of the excess nitrate in soil method is a good indication of potential contamination from nitrogen loading Figure ES-6 seems to indicate that the "estimated excess nitrogen" correlates with the potential for contamination. That is confusing when compared to the following statement made about Figure ES-6 in the top of page xvii – "....The figure indicates that the mass balance method of calculating the end-of-season nitrogen residual is a better predictor of the overall groundwater concentration pattern." These issues create potential for confusion about some very useful concepts presented in this report, and we suggest that some word changes may minimize potential reader confusion. Under the section "Use of current soil nitrate 55 lbs/acre target to protect groundwater," we concur with the report's conclusion that the established end-of-season nitrate concentration recommendations still pose a risk to groundwater. This conclusion is significant and should be emphasized.

27. Page xxiii, third paragraph. There appears to be insufficient evidence to conclude that the maximum fall soil nitrate value is better than the mean fall soil nitrate value for estimating the amount of nitrate that can be leached.

28. Page xxiv, first sentence. Instead of using the phrase "worst-case scenario", we recommend the phrase – "potential for ground water contamination by nitrate would be greater in other regions" to make this point more clear.

29. Page xxiv and page 77, Recommendations. Suggest that the report relate the recommendations back to the goal of determining the effectiveness of NMPs.

30. Page xxiv, second paragraph. These actions may <u>reduce</u> contamination, but will not <u>reverse</u> contamination.

31. Page xxiv, third paragraph. Bullets are used elsewhere... why number these recommendations? Recommendation #8 regarding corn seems to be outside the scope of this study. Recommendation Number 7, sentence seems to be missing the phrase "manure application" after the word "last".

32. Page xxv, last paragraph. Monitoring is needed to evaluate the effectiveness of management practices, and not just improvements. EPA would suggest that routine ground water monitoring be conducted, in which case there is no need to go through the expense of generating an annual excess nitrogen mass estimate as a screening tool.

33. Page 4. The list of questions that seem important; however, the significance of these questions as they relate to the study goal isn't clear.

34. Page 4. We do not recall any discussion of estimating the lag time between nitrogen application and arrival of nitrate at the water table in this report. It is assumed that the lag time could vary significantly since application occurs at different times during the entire growing season. Should this objective be dropped?

35. Page 8, first sentence. Data are shown in Table T.3, not T.2. But T.3 was not included in this report. What is the purpose of the temperature information summarized in Table 1? Suggest referencing the full dataset in an Appendix or providing a more comprehensive summary (e.g., daily or monthly maximum and minimum temperatures).

36. Page 8, Table 1. Units should be included.

37. Page 11. A table outlining what's required in an NMP would be helpful.

38. Page 12. In the dairy nutrient management plans section, the Sullivan and Cogger soil nitrate threshold (15 mg/Kg (55 lb/acre)) appears, and since it is used in other sections and figures it may be good to reference those sections or figures to this section or page. Also in this section there appears to be a key statement concerning the critical effect of timing of soil sampling with the weather. Perhaps these two sentences should be printed in **bold** since they are considered as some baseline references.

39. Page 13, first paragraph. It seems like this first sentence should go into the preceding footnote, since it addresses a technicality for this calculation.

40. Page 13, Field Management section. Additional information would be helpful here. Does this farmer follow a DNMP? Is there guidance that the farmer is using to determine loading rates? Why did he apply almost double the amount of manure nitrogen in 2008 and, to a lesser extent, in 2005? Does he apply all of the manure he has, or does he get it from off-site and why doesn't he apply less? Did he apply at the upper loading rate in 2003 and 2004 or do anything else different that might have caused the large ground water nitrate spike, other than tilling? Were livestock ever permitted in the field?

41. Page 15, third paragraph. If known, provide the depth of the screened interval for the well used for irrigation, and show its location on one of the maps.

42. Page 15, Nitrogen Cycle. The concepts of "fall soil nitrate", "excess nitrogen", and "mass balance nitrogen" seem to first come up in detail after this section of the report. Later on the term "excess total nitrogen" appears. What is the base datum for calculating "excess"? EPA would suggest having a short discussion of all those definitions and calculations at around this section to set the framework for those terms used in the rest of the report. This may be related to our confusion with Figure ES-6 mentioned above.

43. Page 18, last paragraph. On page 15 the water table is listed as rising from 1 to 3 ft instead of 0 to 3 ft. Pick one and be consistent.

44. Page 20, Study Design. Suggest that you relate the results back to the goals of the study.

45. Page 20. On the "Residual" bullet section, the text implies that soil fall nitrate is measured as well as mass of nitrogen? According to Figure 10 and Appendix C, only nitrate was routinely measured in the soil. Is the latter text just intended as a definition of soil nitrate? If so, it should clearly state nitrate-nitrogen. Otherwise suggest that you delete it.

46. Page 21, Figure 9. Arrow needed for soil organic matter. Otherwise same observations as noted for Figure ES-2.

47. Page 22, Figure 10. In this figure the ammonia and organic nitrogen boxes are pink, indicating that they are measured. They are not. By the way, it took awhile searching through this report to locate the table listed as Appendix C. It would help to have this table in the main body of the report because of its importance.

48. Page 23, Methods. More detail should be provided on how the bucket sampling was done, and the relationship of the buckets to the irrigation methods. Also, how does the timing of the sampling and delay between the water entering the bucket and when that water is placed in sample containers affect the concentrations that were in the samples that arrived at the laboratory? Overall the method of collecting the water and then the delay between collection and taking the measurements and analyses merits a discussion of the potential uncertainties.

49. Page 23. Describe how the grower decided how much N to apply. Were N application rates within WSU recommended fertilizer rates for the crop being grown? Were they within the recommendations of the Western Fertilizer Guide? More detail is needed here.

50. Page 27, first sentence. It would enhance clarity to state that the monitoring well network consisted of six shallow and one deeper well. Because it is not quite clear from Figure 13 where the top of the well is relative to ground surface, it would also help to list the approximate distance between the ground surface and the top of the screen for the shallow wells.

51. Page 35, first paragraph. The last line on dairy manure treatment should be stated earlier in the farm management discussion.

52. Page 35, last paragraph. What is the rational basis for assuming that chloride in a shallow well in an agricultural region is negligible? Is there regional shallow water quality data to support this assumption?

53. age 36, middle paragraph. The observation that nitrogen crop uptake appeared to be inversely correlated with nitrogen applied to the field is an important finding and should be highlighted in the conclusions. It should provide further incentive to use less manure when the objective is to maximize yield (as opposed to maximizing disposal). By the way, some of the numbers in the text again do not match with the numbers listed in the figure (434 vs. 436, 716 vs. 736).

54. Page 36, last paragraph. In 2005, the last grass crop was not removed from the field, but the estimate of nitrogen harvested assumed crop removal. This would mean that this estimate is biased low because the nitrogen in this grass is subtracted out even though it never left the field and the real annual excess nitrogen mass would be higher because the grass will decompose and then re-enter the system as part of the original load.

55. Page 38, third paragraph. The sentence is missing "of" before fine-grained – "Samples below 7.5 feet in the other wells had varying amounts *of* fine-grained material."

56. Page 43. Equation 7 missing ( ).

57. Page 45, Dissolved Oxygen section. It is inaccurate to categorically state that denitrification does not occur at dissolved oxygen concentrations greater than 2 ppm. Denitrification is more correctly described as a microaerophilic process rather than as an anaerobic process, and can occur at oxygen concentrations greater than 2 ppm. It is facilitated by lower oxygen levels and is expected to be more active at lower oxygen levels, and this has led some to establish a reasonable upper limit of 2 ppm dissolved oxygen. But in soil and aquifer matrices there can exist a variety of anaerobic microsites with oxygen levels much lower than the bulk water, and so care should be taken not to dismiss this process in aquifer or soil matrices where ground water sampling may indicate higher oxygen values.

58. Page 50. Effects of drain tiles. The report recognizes the use of drain tiles throughout the SBA even though there were none in the study area. On page 50, in the last paragraph, the last sentence states: "The remaining 83% of soil nitrate was presumed to leach to groundwater." That presumption applies in this study field however it may not be true in fields that do have drain tiles. Nitrogen loss via tile drains will have an adverse environmental impact on surface waters.

59. Figure 44 (Plate 6). The term "excess total nitrogen" seems to only appear on a word search on this figure and in Figure ES-6. Is it different than excess nitrogen?

60. Page 53, Equation 8 – Need parentheses around Equation 8 label.

61. Page 53, equation legend. For "S", text should read "from", not "form". Note that the sentence below describes the need for this equation to assume a steady state, which "normally" happens for the crop 3 to 5 years after growth. It seems like that is not the case for this site, based on the water quality data indicating a perturbation in 2004 or prior.

62. Page 54. Table 8 displays the input requirements and expected outputs from a mass balance analysis. This study conducted by researchers at Washington State University was conducted with the full cooperation of the producer that operates that tract of land. The text recognizes that a challenge of conducting an accurate mass budget analysis is that it relies on the accurateness of records kept by the producer. Some of the information that a producer would be expected to maintain, then provide to Ecology includes, but is not limited to:

    - Listing of all fields where land application occurs.
    - When applications are made.
    - How applications are made (injected, broadcast, mixed with irrigation water and sprinkled etc.)
    - What kind of waste (liquid, solid, compost, etc.) and bedding content if applicable.
    - The nutrient content of all waste applied.
    - Application method and length of time between application and incorporation.
    - The volume of applied waste, tons or cfs.

- The current crop and crop rotation. If irrigated, timing and volume of applications.
- If commercial fertilizer is applied, rate, form and method of application.
- The yields for all crops.

63. .Page 55, Figure 45. Previously the report refers to mean fall soil nitrate, which we assume is the average of all of the soil nitrate values across the site from September through November for any given year (is that correct?), and it provides a graphical representation of the values in Figure ES-4. Why then does Figure 45 introduce a separate set of numbers describing fall soil nitrate derived from maximum values? Why provide this estimate at all, since fall soil nitrate is not a parameter measured or estimated for use in Equation 8, which this Figure is supposed to represent?
64. Page 57, first bullet. Is this saying that because of the time of travel, any high nitrate concentrations in ground water upgradient of this study at the time of this study would not reach the wells during this study? What about possible high concentrations upgradient of the study 5 to 10 years ago which could now theoretically be upgradient of these wells but within the study site boundaries during the time of the study?
65. Page 57, third bullet. How long has this upgradient site been receiving manure application? Twenty years, like the study site? Could nitrate from previously applied manure make it to this study site within this time period? These arguments don't appear to be supported. Additionally, it would be helpful to describe the current and historical land use around the study site and plot the locations where manure is being applied.
66. Page 59, third paragraph. Nitrate is like chloride <u>only</u> in that it has minimal sorptive properties and both are anions. It is not conservative because it is easily transformed to other nitrogen species. It may be "associated with manure application" like chloride, but indirectly so, since it is absent in manure and is only formed from manure ammonia through nitrification when oxygen is available. Chloride and nitrate plumes originating from manure do not necessarily coincide.
67. Page 59, second paragraph from bottom. The wrong figure is referenced; Figure 29a shows October water table contours in 2007.
68. Page 62, first paragraph. Should be "GDUs" in parentheses instead of "Gus"?
69. Page 62 . Equation 8 is on page 53. This should be Equation 9, and the equation label needs to be in parentheses and the text modified accordingly.
70. Page 65, second paragraph. Some of this discussion on chloride and tillage already took place on page 59 and need not be repeated.
71. Page 65, Equation 10. The equation label needs to be in parentheses, and the text at the bottom of the page needs to refer to this as Equation 10.
72. Page 68, Figure 54. Is this mean fall soil nitrate? What is the significance of the green circled areas in relation to the target fall soil nitrate? Does it matter whether it was above the target level just before the growing season in January? In other instances it was way

above the target level a month or so earlier, but still ended up being pushed down by high rainfall in those earlier winter months. Under either circumstance, the load is being pushed down during cold weather when microbial activity is minimal. Note that 2006 and 2008 had very heavy November rainfalls (~ 11 inches) that drove this mass down earlier than observed in the green circled areas.

73. Page 69, Equation 11. The equation label needs to be in parentheses, and the text above it to refer to this as Equation 11.

74. Page 70. There is an "eith" highlighted which needs correction.

75. Page 71, Figure 55. Same comments as for Figure ES-10.

76. Page 71, first paragraph. This discussion in this section does not relate to the title regarding the protectiveness of current guidelines. The report does not address the current guidelines or propose changes based on the study; it simply references an alternative based on recharge provided by another researcher and questions the validity of setting a guideline based on recharge. The focus should be tightened or the section title should to be changed.

77. Page 72, top paragraph. Again, the stated dissolved oxygen threshold for denitrification is too definitive and is misleading.

78. Page 73. The conclusions section could be shortened to enhance its impact. The purpose of the study changes in the conclusions section: "The purpose of this study was to document the impacts of manure application on groundwater beneath a dairy field overlying the SBA." This conflicts with an objective stated earlier which is to determine the effectiveness of NMPs. This inconsistency should be reconciled.

79. Page 73, first paragraph. This should state 22 acres instead of 20 acres to be consistent with the rest of the report

80. Page 73, Conclusions. Reiterating the definitions of the factors in the conclusions section detracts from the presentation of the conclusions. Perhaps just briefly list the factors prior to the discussion of the conclusions.

81. Page 74, last paragraph. Should be modified to "...the use of soil nitrate predicts..." A qualifier should be added stating that these preclude the use of soil nitrate for *reliably* predicting ground water impacts. In general, soil nitrate can indicate trends.

82. Page 75, second paragraph. EPA concurs with the conclusion "that direct monitoring of groundwater using monitoring wells screened across the water table is needed to accurately characterize impacts of manure application on aquifer water quality" and suggests that this conclusion be articulated in the Executive Summary as well.

83. Page 76, last paragraph. "Worst case" and "best case" are vague phrases subject to interpretation. Perhaps a better way of phrasing this would be "These points suggest that the results observed during the study might be unique to this portion of the aquifer and that the same manure application practices would most likely lead to greater nitrate contamination in other regions of this aquifer".

84. Page 77, second paragraph. This general recommendation for conducting excess mass balance analyses does not seem to be supported by the evidence in the report, which shows it to be a poor predictor of leachate nitrate concentrations.

85. Page 77, third paragraph. Suggest using bullets instead of numbers for consistency with the rest of the report (or at least start with number one instead of number twelve). Some of these recommendations seem to be more common-sense rather than being generated as a result of this study. One could easily add many more recommendations like "make sure that manure is distributed evenly" or "don't let livestock into the fields" when these are not experimental variables being addressed in this study. Recommendation No. 16 is an example; nowhere in this study was there an analysis of any deleterious effects caused by using fertilizer in those instances where it was used. It is common sense to not use fertilizer when one does not have to, but there is no data in this report that says one should not substitute fertilizer for manure. Also, in this recommendation, the second sentence is essentially identical to recommendation No.17. Some recommendations could be combined, like Nos.18 and 19.

86. Page 77, Recommendation No. 13. While the mass budget process addresses the application rates of nutrients, this recommendation gets to the root problem of migration of nitrogen to groundwater. Land application of waste during high precipitation periods, especially when crops are dormant or at least have reduced growth activity, encourages the migration of nitrogen through the root zone where it is lost to the environment. EPA supports limiting winter land application in this environmental setting and recognizes that facilities may need to construct additional storage capacity. Since waste is predominately handled as a slurry, construction or modification of concrete or similar storage containers may be required.

87. Page 78, last section. These monitoring strategies should be in place for routine operation, not just when management improvements are made. If a case is to be made for conducting annual excess nitrogen mass balance evaluations, it should be placed in this section, rather than in the section on reducing nitrate loading, because it does not seem to correlate with nitrate loading to ground water and is in essence an extensive monitoring program.

88. Page 138, Table M.3. Relocate footnote 2, because 2005 is not an estimate, but the gallons applied may be an estimate. The units for the displayed N loadings should be indicated.

89. Plate 1, Figure 26. This figure should be clarified. It appears that the tops of the wells are a few feet below ground surface, which does not correspond with the well logs or Figure 13. Considering the annual rise of the water table, it is important to depict where the screened intervals are relative to ground surface. Is the red line intended to represent the ground surface? It would be helpful to expand this figure horizontally so that well AK725 can be displayed alongside of deep well AKG726. The well pairs could be placed more closely together to better reflect the B'-B transect line.